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DETECTION OF MOVING TARGETS IN PERIPHERAL VISION.(U)
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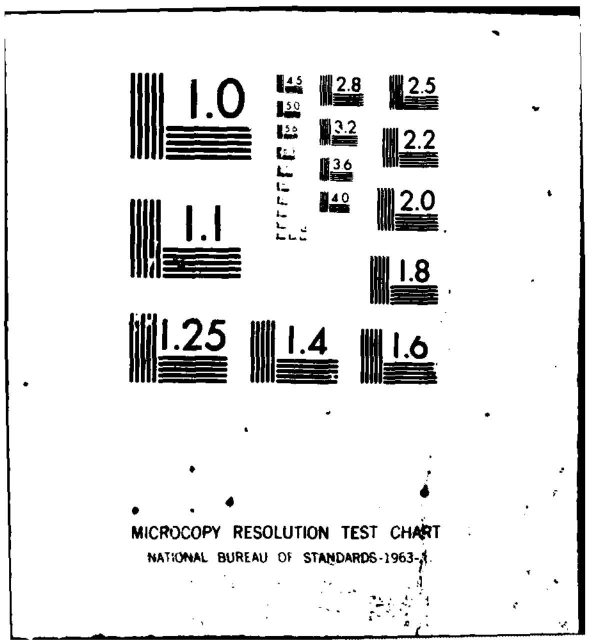
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(6) DETECTION OF MOVING TARGETS IN PERIPHERAL VISION

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Foreward

The research problem reported herein was formulated while the principle investigator worked in the USAF/ASEE Summer Faculty Research Program at Wright-Patterson AFB, Ohio

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INTRODUCTION

Human detection of a moving target is a function of (1) target size and contrast and (2) target velocity. Recent work in human psychophysics and animal electrophysiology has shown that visual information is processed in many "channels," each specialized to detect a particular aspect of the visual stimulus. For example, the human visual system appears to contain channels sensitive to spatial frequency (or target size). It has also been shown that different spatial frequencies are processed at different temporal rates (Tyman and Sekuler, 1974; Breitmeyer, 1975), suggesting that detection may depend upon an interaction of target size and velocity.

In addition to channels specific for spatial frequency, velocity-sensitive channels have been found that are specific for direction of movement (Pantle and Sekuler, 1968). Other experiments with drifting gratings show that their sinusoidial components interact differently at various speeds (Pantle, 1973). These data suggest that the visual system may have separate mechanisms for the detection of spatial contrast (size) and temporal contrast (movement) (Tolhurst, 1973). Presumably, detection of an object in motion will be mediated by both of these two detection mechanisms.

Many studies involving moving targets have concentrated only on the motion itself. That is, the target object is always above visibility thresh-hold and the observer detects only motion. Johnson and Leibowitz (1976), using a relatively large target (0.95°) with durations of 0.1 to 1.0 sec, found that motion thresholds were determined by a constant displacement (v x t) of the test stimulus. Thus, for high velocity targets, a short exposure time is sufficient for detection of movement, whereas at low velocities a long exposure time is required. Similar results were obtained by Cohen and Bonnet (1972) using a smaller target (6').

The effects of target and background luminance on motion detection are confusing. Henderson (1971) using a small target (1.4') found that motion discrimination is not energy dependent, but depends upon target exposure duration and distance travelled. In his study, target luminance was not found to be an important parameter for the low adaptation levels used. Using a different paradigm employing a forced-choice technique, Brown (1931) found that increased background brightness resulted in decreased phenomenal movement. Leibowitz (1955) has found that velocity thresholds tend to become lower and asymptotic as target luminance increases. The value of the asymptote depended upon exposure duration.

In summary, then, it appears that motion detection depends upon both exposure time and retinal displacement. Most studies of target and background luminance show lower motion detection thresholds for higher luminances. Of course, motion detection is only part of the problem when one considers detection of moving targets. Target size and contrast are also important.

Detection, resolution, and identification of static targets constitute a problem in visual acuity (VA). Usually VA studies employ parameters such as size, contrast, and retinal eccentricity. In general, acuity is best in the fovea and falls off rapidly in the periphery. Smaller objects are more easily seen at higher adaptation levels and at high contrasts. For very brief exposures (< 0.1 sec) of small targets, VA depends upon a size-time reciprocity. Graham (1965) has thoroughly reviewed VA and the details will not be elaborated here. What is important is that it be recognized that neither movement detection alone nor VA by itself can predict detection of very small moving targets in the periphery. Detection is probably mediated by <u>both</u> the spatial and temporal channels mentioned earlier.

The detection of small, moving targets is usually considered as a class of problems involving dynamic visual acuity (DVA). Much of the DVA work is concerned with foveal acquisition and tracking of small targets (Brown, 1972; Barmack, 1970; Miller, 1958). As such it is really an index of eye-movement performance since the observer has already detected the target in the visual periphery. There are very few DVA studies that have held eye position fixed. In one such study, Brown (1972) measured resolution thresholds for Landolt rings presented at several eccentricities. In general, he found that target-size thresholds increased with target angular velocity. However, for very low velocities, there was a reduction in target-size threshold over that for the static presentation. This finding confirms the previous assertion that both size and movement are important in detecting moving targets. It should be noted, though, that his task employed recognition, not simple detection.

Most motion detection studies are done with positive contrast targets; bright targets are projected on dim backgrounds. This procedure lends itself to simple instrumentation to move the bright target spot but has the disadvantage that high adaptation levels cannot be used. The reverse situation where dark test spots move on light backgrounds is difficult to instrument since the background intensity must remain constant as target contrast is changed. Many workers avoid the problem of target contrast by assuming that positive and negative contrast objects are equally detectable. This appears to be true at least for static targets at high background luminances (Blackwell, 1946). For dim backgrounds, darker objects have less visibility (Patel and Jones, 1968). Contrast sign has not been systematically studied for detection of moving targets.

METHOD

To investigate the effects of target size, contrast, eccentricity, and velocity on detection thresholds, a series of experiments were carried out in which thresholds were determined when the above stimulus conditions were systematically varied. The procedure differed from those previously reported in the literature in that a high adaptation level was used and targets were small spots rather than the sinewave gratings that typically have been employed in studies on motion detection (Konderink, et. al., 1978).

Subjects

Three male subjects aged 21, 22, and 38 were used in the study. All subjects had extensive experience in psychophysical studies and had normal or corrected-to-normal vision.

Apparatus

Stimuli were presented by means of a two-channel Maxwellian-view optical system. A schematic of the optical arrangement is shown in Fig. 1. The light from a regulated direct current 250 watt incandescent source (S) was directed into two channels. Channel 1, the background channel, was attenuated by a combination of a circular neutral density filter (ND1) and fixed filters (F1) to produce a retinal illuminance of 1300 trolands. This corresponds to a luminance of approximately 1000 Ft-Lamberts for the normal viewer. Luminance calibration was performed according to the method outlined by Westheimer (1966). Channel 2, the target channel, contained an aperature (A2) in the collimated beam to restrict the field to a bright spot that was superimposed on the luminous background by the beam-splitting cube (BSC). The target spot was oscillated with a linear velocity profile by means of a mirror galvanometer

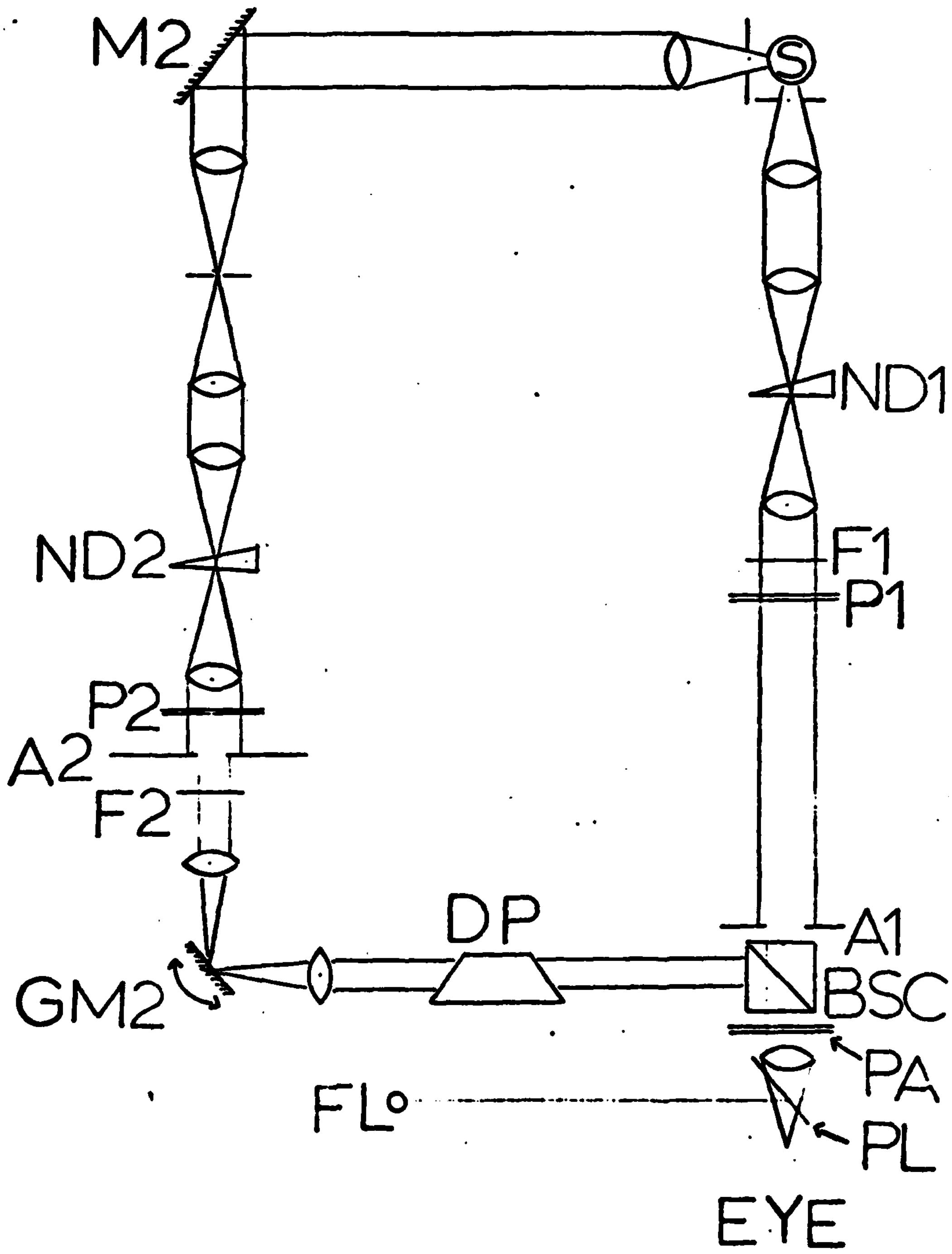

Fig. 1. The two channel Maxwellian-View optical system.

(GM2) coupled to an operational amplifier and signal generator. Direction of movement, horizontal or vertical, was controlled by appropriate rotation of a dove prism (DP). The target and background channels were combined at BSC and directed into the viewer's right eye.

The fixation light (FL) was arranged so that it could be viewed by reflection from a pellicle (PL). By suitable adjustment, fixation resulted in the subject viewing the stimuli at various retinal eccentricities. A dental bite was used to stabilize head position.

To produce dark test spots (ie. negative contrasts) polarizers (P1 and P2) were added to the optical system. They were physically coupled together, out of phase, such that an increase in transmittance in one channel corresponded to a decrease in the other channel when viewed through the polarized analyzer (PA). Aperature A2 was replaced by a clear sheet of film which contained an appropriate-sized dark spot at the center. Thus, the quantity of veiling light for contrast reduction could be varied while the sum of the background light from the two channels was held constant. Contrast was calculated according to the expression: $C = L_{(max)} - L_{(min)} / L_{(max)} + L_{(min)}$.

Procedure

Aperatures or spot sizes were chosen such that subjects viewed test spots of 5', 15', or 30' arc against a luminous background that was restricted by A1 to 3.75° visual angle. This field size was dictated by the area of the face of DP. The mirror galvanometer was driven by a triangle wave so that linear target velocities of 0', 3', 60', or 120' arc/sec were produced. Target excursion was always 2.7° in either the horizontal or vertical meridian.

Once adapted to the background luminance, subjects adjusted ND2 (positive contrast condition) or P1 and P2 (negative contrast condition) until the moving test spot was at threshold. All thresholds were determined while subjects maintained the fixation dictated by FL. Using block randomization, each subject made 5 threshold settings for each test condition. A full factorial design was employed to determine the thresholds for the positive contrast horizontal movement conditions. The 15' arc target was omitted in the vertical movement conditions of the positive contrast studies. Selected horizontal movement conditions were studied in negative contrast.

RESULTS

Positive Contrast

The results of the positive contrast studies are summarized in Figures 2-6. Each data point represents the mean contrast of 3 subjects who made at least 5 determinations for each condition. Several trends in the data are readily apparent. Thresholds decrease as target size increases. There is also a slight tendency for thresholds of large targets to decrease with velocity, although this effect is minimal when compared to that produced by target size. In general, the direction of movement, horizontal or vertical, has little effect on contrast thresholds.

Retinal eccentricity has a very large effect on ease of detection. Foveally fixated targets always have a lower threshold contrast than targets viewed in the periphery of the visual field. The small 5' targets were difficult to detect at 15° eccentricity and thresholds could not be accurately determined unless the target was moving rapidly.

Field Size

Limitations imposed by the apparatus restricted field size to 3.75° in the negative contrast condition. To enable comparisons to be made between the positive and negative contrast data, the positive contrast studies were also limited to this field size. Naturally, the question of the effect of field size upon contrast thresholds arises. A study was performed in which two field sizes, 3.75° and 9°, were tested for a 30' positive contrast target. The results are shown in Table I.

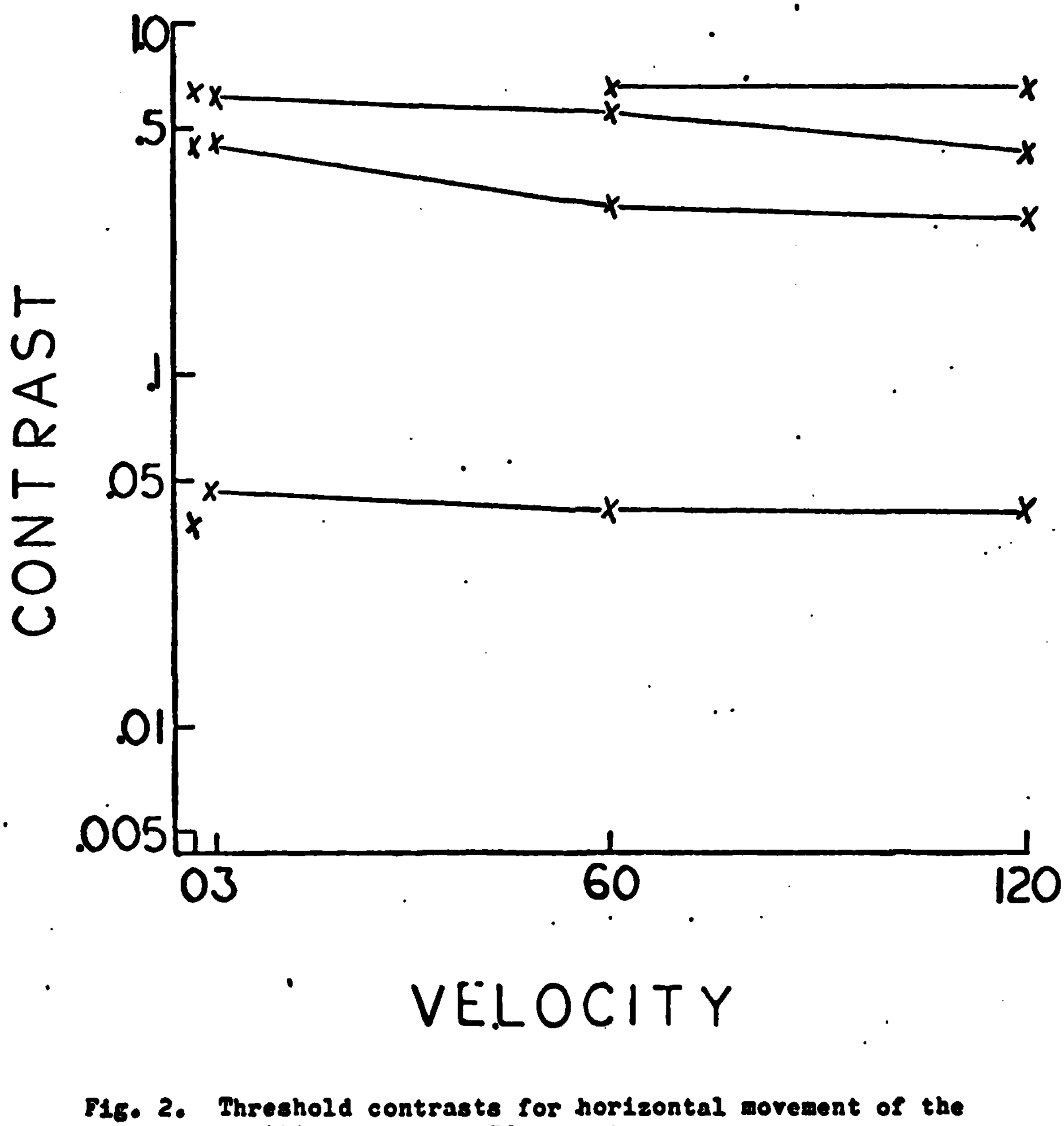

Fig. 2. Threshold contrasts for horizontal movement of the positive contrast 5' target.

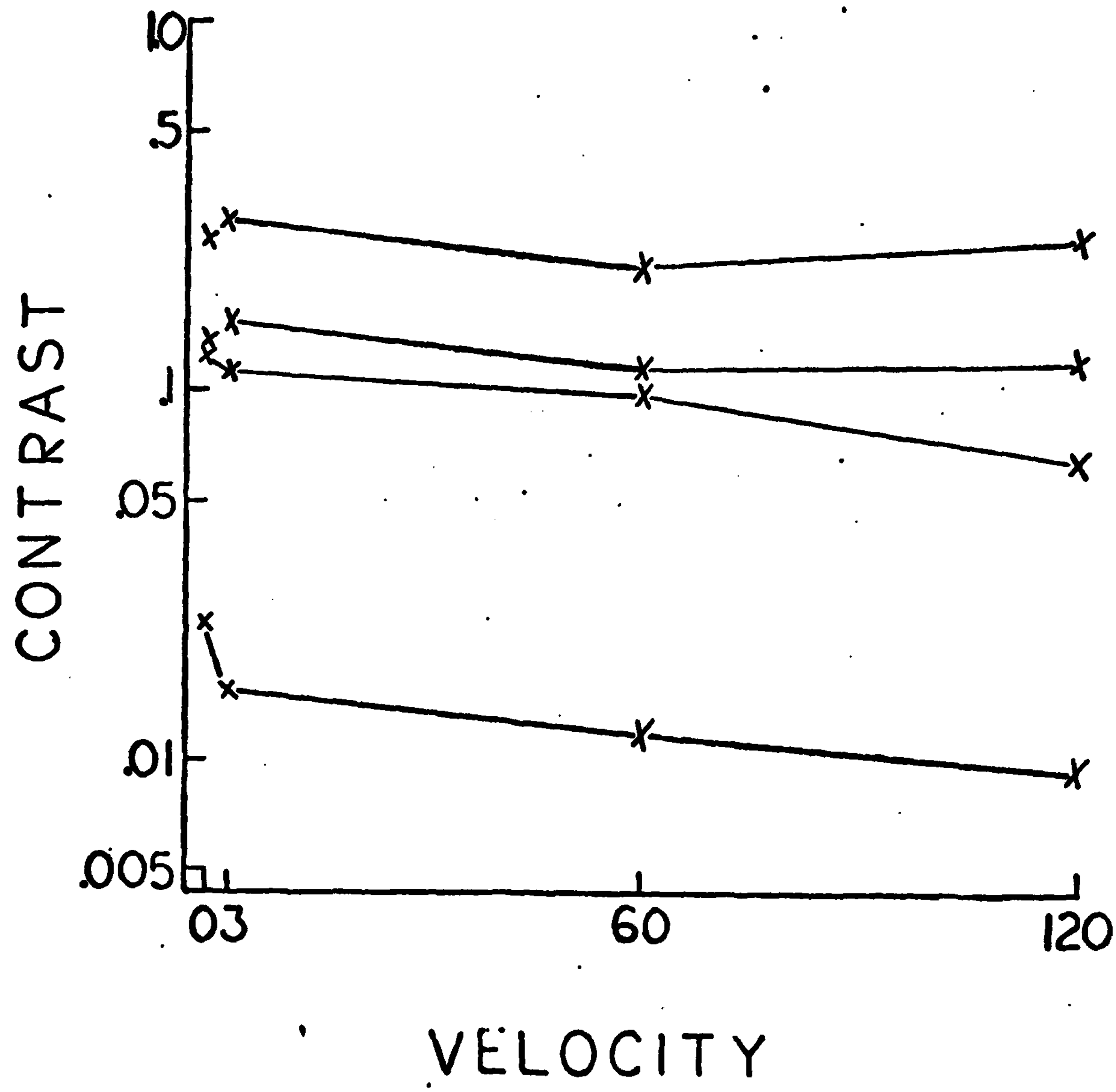

Fig. 3. Threshold contrasts for horizontal movement of the positive contrast 15' target.

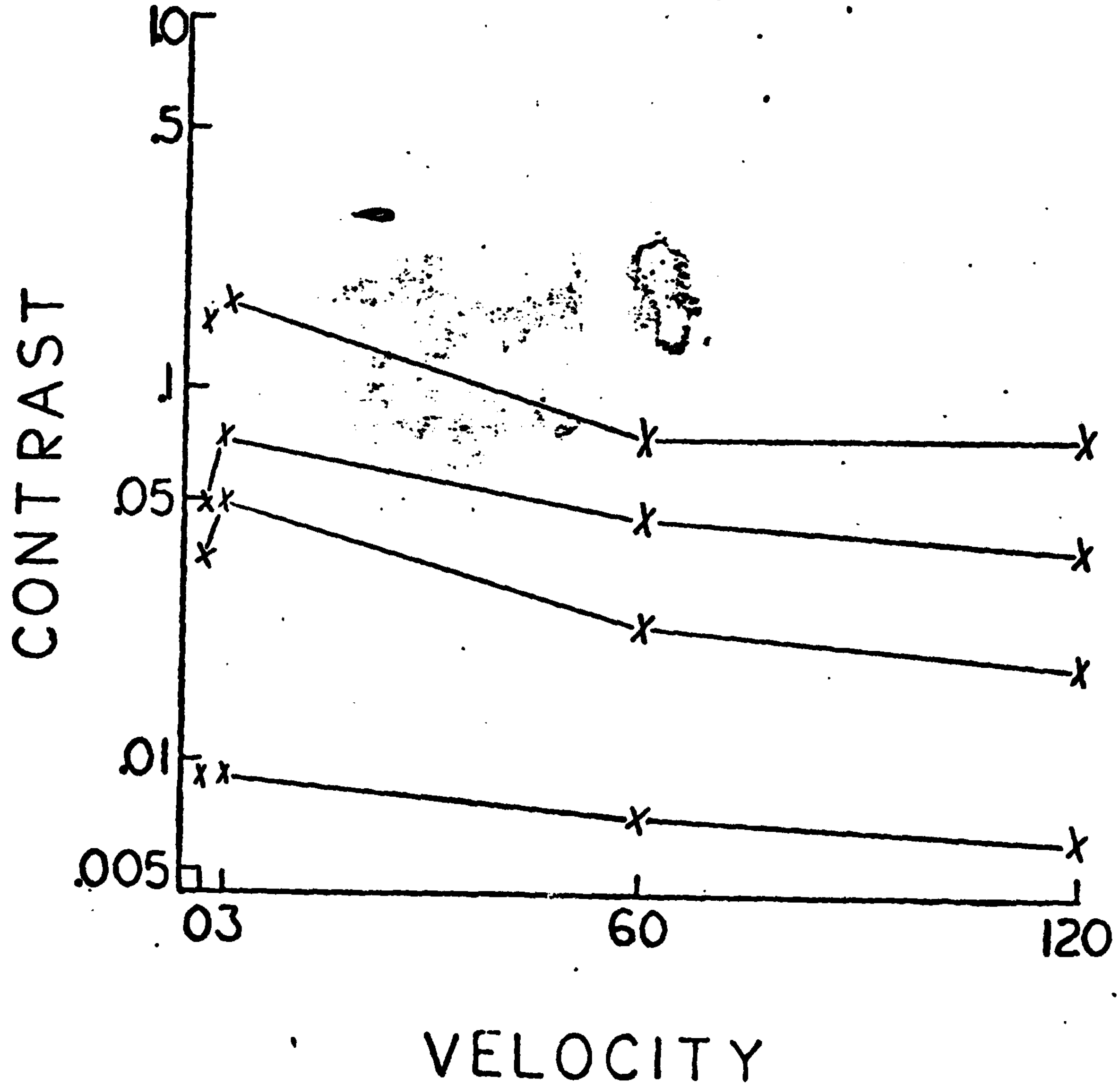

Fig. 4. Threshold contrasts for horizontal movement of the positive contrast 30' target.

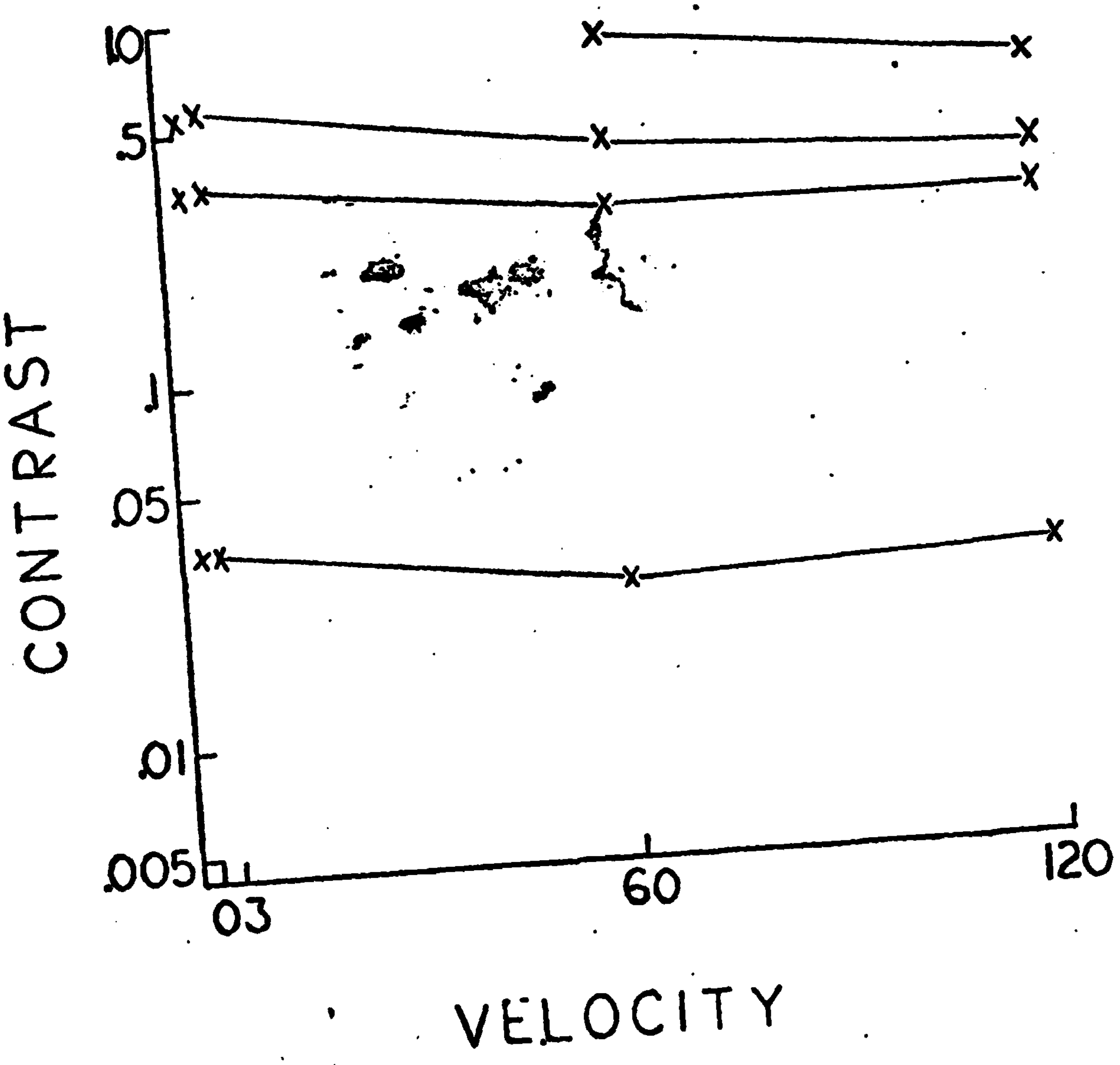

Fig. 5. Threshold contrasts for vertical movement of the positive contrast 5' target.

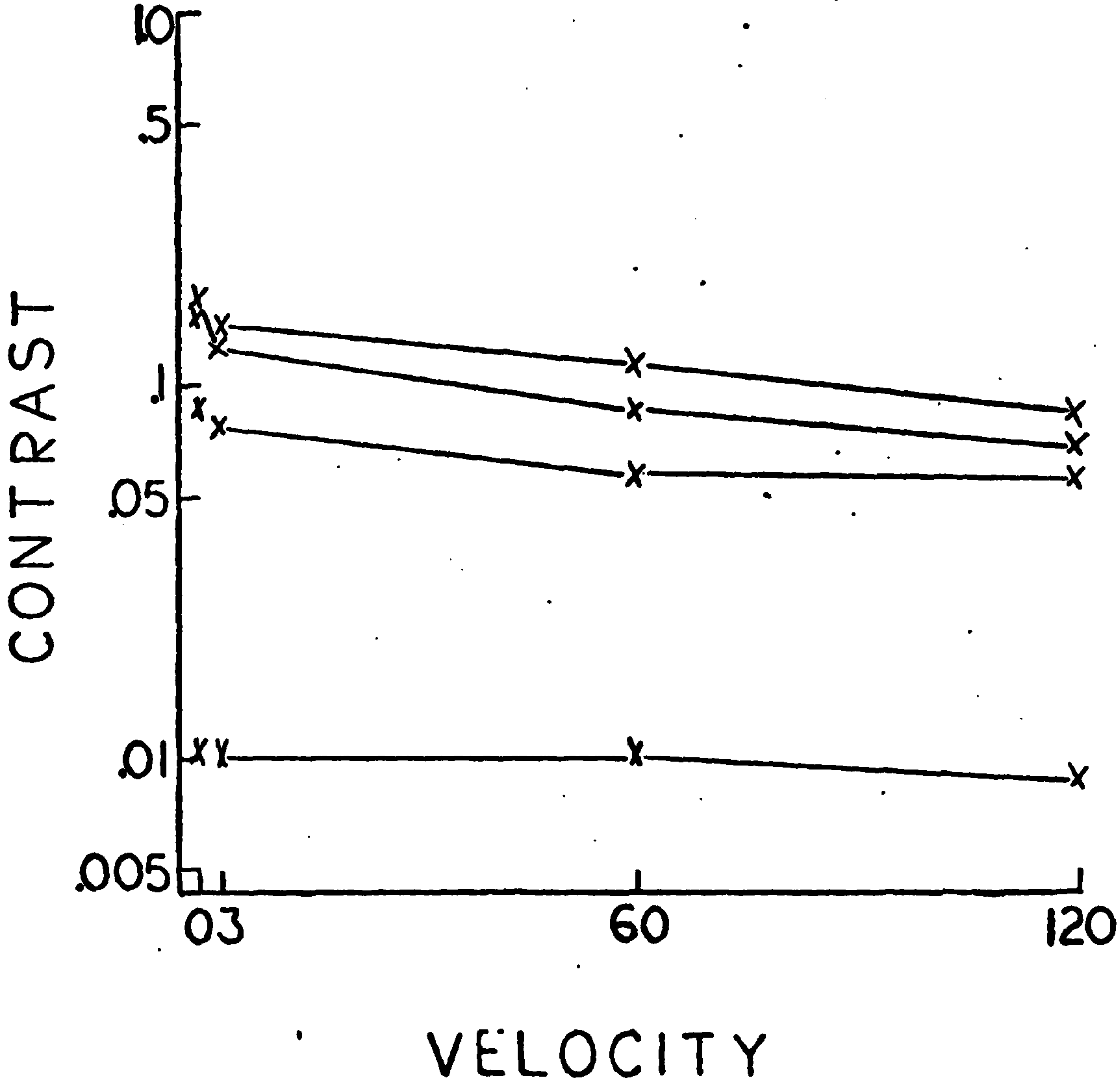

Fig. 6. Threshold contrasts for vertical movement of the positive contrast 30' target.

Table I

The Effect of Field Size upon Contrast Threshold

Field Size	Target Eccentricity	Threshold Contrast	95% Confidence Limits
3.75°	10°	.105	.100-.113
9°	10°	.101	.090-.112
3.75°	15°	.114	.107-.121
9°	15°	.099	.088-.111

It is apparent that the confidence intervals show considerable overlap, indicating that the different field sizes do not significantly effect thresholds for 10° target eccentricities. For the 15° eccentricity, the large field tends to lead to lower contrast thresholds. Thus it appears that the small field data may be most relevent for predicting detection when retinal eccentricity does not exceed 10°.

Negative Contrast

The results of the negative contrast studies are summarized in Figures 7 and 8. The data show several trends that are similar to the positive contrast studies. Thresholds decrease slightly as target size increases. Thresholds also decrease very slightly as velocity increases. The most striking effect shown by the negative contrast data is the large increase in thresholds relative to the positive contrast work. The differences are large and consistent. Since this effect is not predicted in the literature, the apparatus calibration was carefully checked. The luminances and contrasts are correct. Thus, it must be concluded that, for the conditions employed in this study, negative contrast targets are more difficult to detect than positive constrast ones.

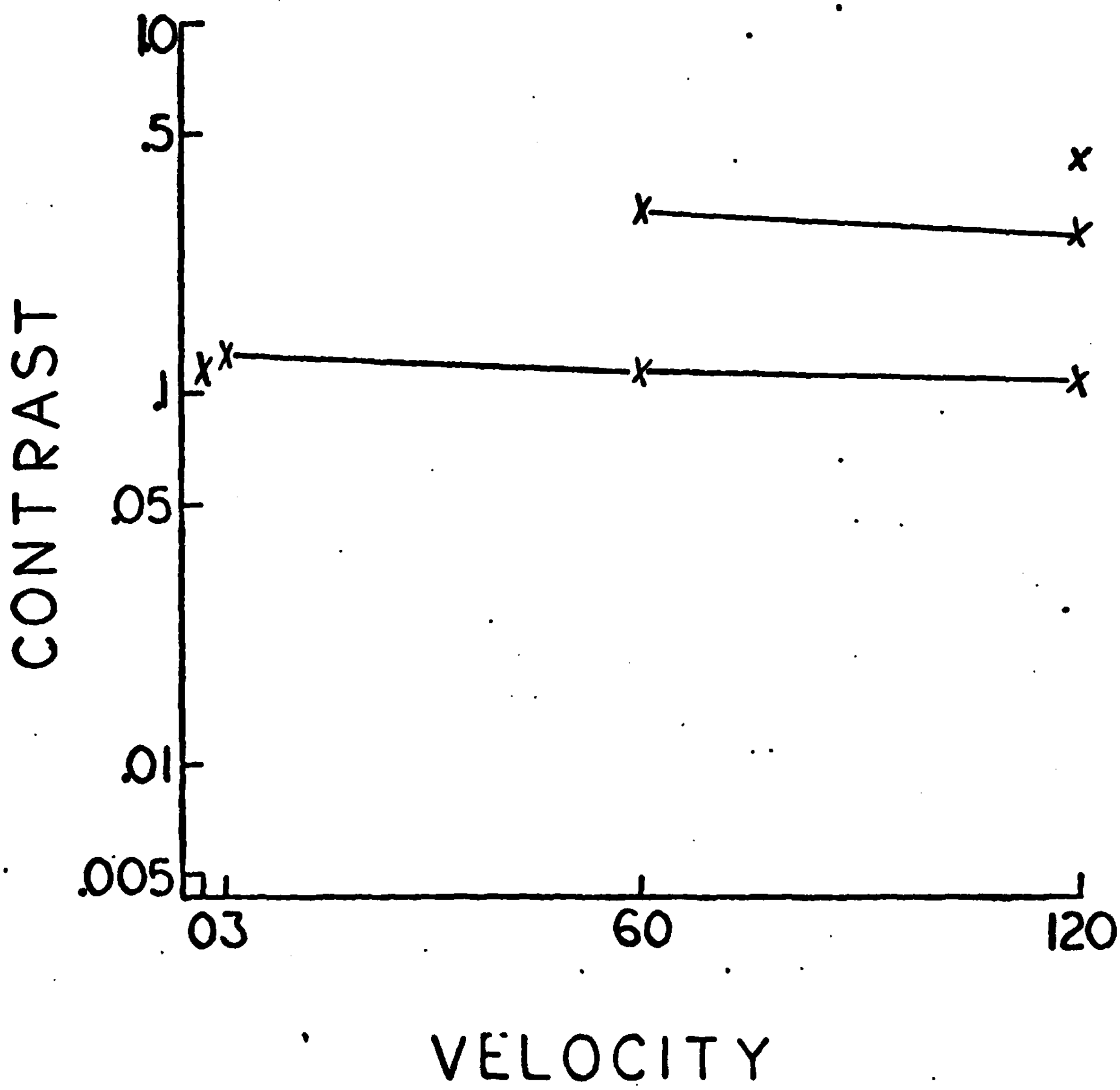

Fig. 7. Threshold contrasts for horizontal movement of the negative contrast 5' target.

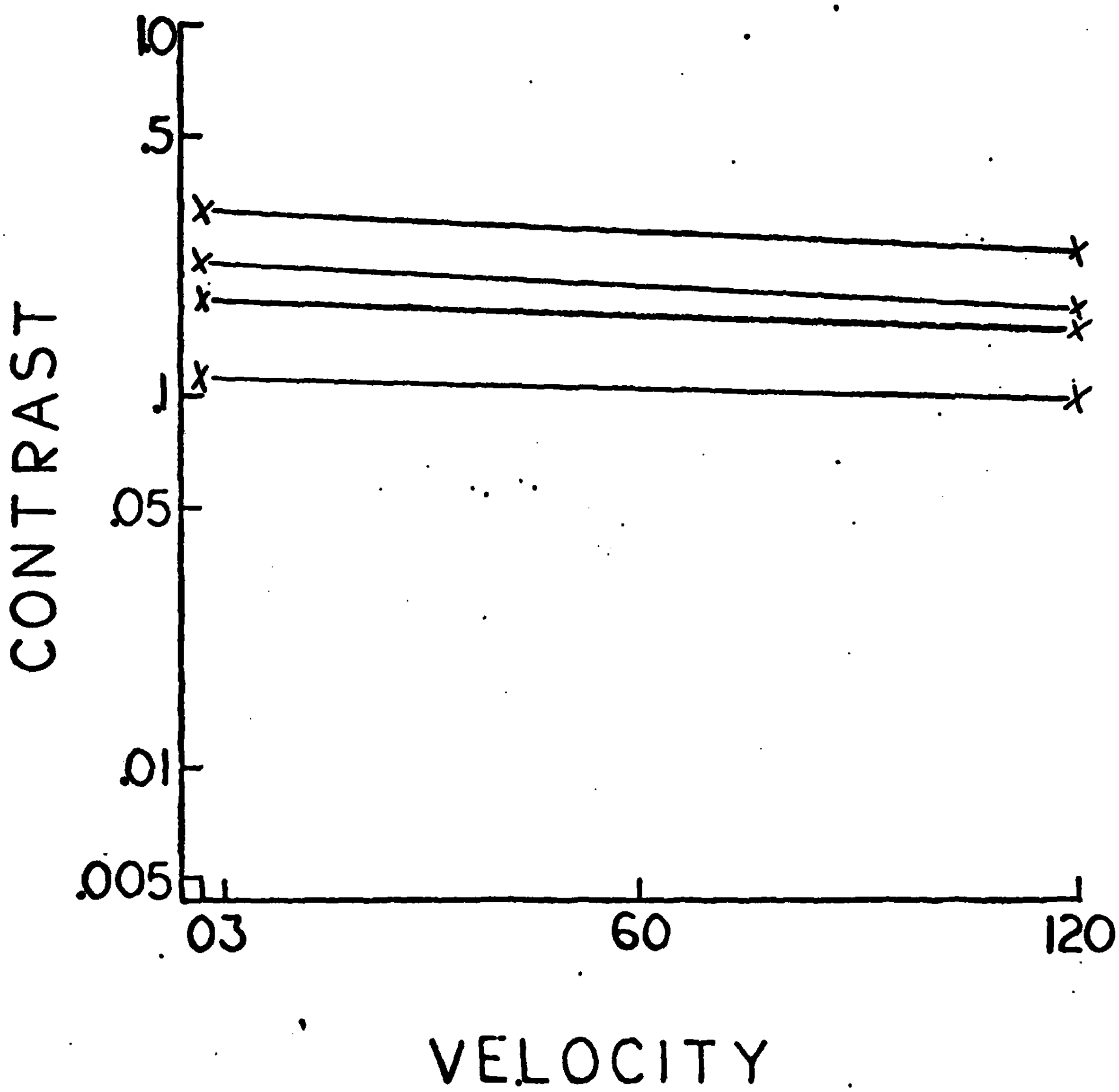

Fig. 8. Threshold contrasts for horizontal movement of the negative contrast 15' target.

DISCUSSION

The data obtained in the studies reported show that target velocity has only a small effect on detectability. Target size appears to influence detection in that large targets are easier to detect. Targets presented to the visual periphery are always more difficult to detect than foveal targets. These results are in accord with expectations based on the existing literature.

Negative contrast targets appear to be much more difficult to detect than positive contrast ones. It is not clear from theories of visual function why this should be the case. Of course, very little is currently known about the interaction of dynamic and static visual channels and most of the existing literature concerns static detection. Until more data are available, it will not be possible to provide a theoretical framework for these data.

The negative contrast results have important implications for those who build models of target detection. To accurately predict detection, models will have to consider contrast sign. The data provided herein should aid in the development of these models and will, hopefully, stimulate more work in dynamic visual target detection.

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Visual contrast thresholds were investigated as a function of: target size, contrast, eccentricity, and target velocity. In general it was found that, while large targets were easiest to detect, target velocity had little effect on detection thresholds. Retinal eccentricity and contrast sign seem to be the variables of most importance. Targets beyond ten degrees in the periphery were difficult to detect except at high velocities. Negative contrast targets have very high detection thresholds compared to

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positive contrast stimuli. This finding is especially relevant to models of target detection.

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